smaller perturbations in the flow field can destabilize the Taylor bubble and break it up into smaller bubbles. Therefore, high aspect ratio channels, namely of aspect ratio equal to or exceeding 5, more preferably equal to or exceeding 10, promote more stable partial boiling.

[0243] **FIG. 15** shows the variation of pressure drop with average heat flux for the device. As the heat flux increased, more liquid was evaporated and hence the pressure drop increased.

[0244] **FIGS. 16 and 17** compile the overage temperature, the difference between the average (excluding the two end points) wall temperature (T_w) and the saturation temperature (T_s), versus the boiling number (Bo) and the SR number, respectively, for the data described in **FIGS. 12 and 14**. This data set excludes the data point where dry out occurred in **FIG. 19**, as it isn't indicative of the high heat transfer convective boiling seen for the other data. The area beneath the points for both **FIG. 16** and **FIG. 17** indicates as stable nucleate boiling operation.

[0245] The shear stress during boiling for this example had an average of 7.5 Pa, a maximum shear stress of 10.6 Pa and a minimum shear stress of 1.7 Pa at a flowrate of 12 mL/min per microchannel of water for the 24channel. For this case, the shear rate average over the channel length was 7425 hz, the maximum shear rate was 10253 hz, and the minimum shear rate in the channel was 2036 hz. The shear stress and shear rate was calculated using computational fluid dynamics based on the channel geometry, flowrate per channel and the flow regime, where the Reynolds number is less than 2000 for a laminar flow.

EXAMPLE 4

[0246] Partial boiling heat transfer is applied to vinyl acetate monomer (VAM) production in micro-channels. The micro-channels by combination of the plates had cross-sectional dimension 0.05 mm×1.3 cm. The gap on the reaction side is 1 mm and on the coolant side is 1 mm. On the reaction side, a mixture of ethylene (C2H4), acid gas (CH3COOH) and oxygen (O2) is fed at temperature 160 C and pressure 8 atm. The micro-channel is packed with micro-pellet catalyst with a void fraction around 0.4.

[0247] The VAM producing reaction release heat into the packed bed and then the heat conducts through the channel walls to the surface on the coolant side, where the coolant vaporates. The coolant used in this example is water. At the beginning of the catalyst bed, the reactants are at the highest concentration level and the reaction rate is at the maximum. This leads to the asymmetrical temperature profile along the catalyst bed. Accordingly, the heat flux profile on the channel wall (**FIG. 19**) also shows the peak neat the inlet of the reactor.

[0248] The temperature hot spot near the beginning of the catalyst bed is detrimental to the selectivity of the desired product—VAM and the product yield. Also, the catalyst life time will be shortened due to the high temperature. It is desirable to operate the VAM reactor at the iso-thermal condition, or temperature variation along the reaction path within the tight range. In **FIG. 20**, temperature profiles along the reactor length using various heat removal schemes are compared. It clearly shows that the temperature variation along the reactor length is much tighter when partial boiling is applied to remove the heat. Another advantage of applying partial boiling heat removal is that high active catalyst can be used to give temperature profiles without large spikes, meanwhile the single phase cooling is not feasible under this condition.

[0249] The partial boiling heat transfer integrated with the micro-channel VAM reactor enable operation under higher process output. **FIG. 21** shows the temperature profiles along the centerline of the catalyst bed under four contact time levels with single phase heat convection as the heat removal method. The gap size of the coolant channel is 1 mm. The wall thickness is 0.5 mm and the channel gap on the process side is 1 mm inch also. The coolant flow stream has the average velocity of 0.3 m/s. Under lower contact time, or larger throughput, the temperature rise in the catalyst bed is larger. The design requirement of temperature rise is 10° C. above the inlet temperature, which is 180° C. in this case. With single phase heat convection as heat removal method, the reactor can not run at the contact time shorter than 250 ms. At 250 ms contact time on the process side, if partial boiling is the choice of heat removal method, the temperature rise in the catalyst bed is less than 10° C., well within the design allowable range.

EXAMPLE 5

[0250] A multiple channel Fischer-Tropsch synthesis reactor was tested. The reactor designed had reactor unit operation channels for reactor microchannel in vertical orientation with flow in the direction of gravity. The heat exchanger microchannels were oriented in the horizontal orientation, cross-flow to the process channels. **FIG. 22*a*** shows the view of both sets of channels in the main body of the reactor. The reactor was constructed from stainless steel 316. There are 9 process channel that are 0.050 cm tall by 12.5 cm wide and 11.3 cm long, of which 7.5 cm are used for a catalyst bed. The catalyst bed was made up of an alumina support material with cobalt. There are 10 heat exchanger channel rows, with each row flanking a process channel. In each row there are 11 microchannels that are 0.750 cm tall and 0.270wide and 15 cm long, with 0.030separating channels in the row and 0.090" separating row from row.

[0251] To get equal flow into all sections of the reactor, a set of orifice plates were used to push flow to the outside corners of the device, a problem seen in flow testing. These orifice plates are shown in **FIG. 22*b***. Flow enters the header shown in **FIG. 22*b*** and distributes through the outer perimeter orifice and then through another straightener prior to entrance into the channels. Temperature measurement of the system's core was made through thermowells pictured in **FIGS. 22*a*** and **22*b***. These thermowells were close to the outer heat exchanger channels and would indicate the presence of temperatures higher than what is expected from partial boiling conditions.

[0252] Therminol LT was fed at 50 mL/min and the reactor was fed a 2:1 molar mixture of hydrogen to carbon monoxide at a contact time of 250 milliseconds. **FIG. 22*c*** illustrates the time on stream data for the temperature ramp up to conditions and the initial performance. The reactor shows that the inlet coolant temperature varies during the temperature ramp up to the set point condition. Once the coolant reached the set point temperature the skin temperatures of the process spiked to values substantially higher